Adapting & Openness: Dynamics of Collaboration Interfaces for Heterogeneous Digital Orchestras

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ABSTRACT

Advanced musical cooperation, such as concurrent control of musical parameters or sharing data between instruments, has previously been investigated using multi-user instruments or orchestras of identical instruments. In the case of heterogeneous digital orchestras, where the instruments, interfaces, and control gestures can be very different, a number of issues may impede such collaboration opportunities. These include the lack of a standard method for sharing data or control, the incompatibility of parameter types, and limited awareness of other musicians' activity and instrument structure. As a result, most collaborations remain limited to synchronising tempo or applying effects to audio outputs.

In this paper we present two interfaces for real-time group collaboration amongst musicians with heterogeneous instruments. We conducted a qualitative study to investigate how these interfaces impact musicians' experience and their musical output, we performed a thematic analysis of interviews, and we analysed logs of interactions. From these results we derive principles and guidelines for the design of advanced collaboration systems for heterogeneous digital orchestras, namely *Adapting (to) the System*, *Support Development*, *Default to Openness*, and *Minimise Friction to Support Expressivity.*

Author Keywords

collaborative musical interfaces, digital orchestras, cooperation, heterogeneous

CCS Concepts

•**Human-centered computing** → *Collaborative interaction;* Interface design prototyping; •**Applied computing** → **Sound and music computing;** *Performing arts;*

1. INTRODUCTION

Digital Musical Instruments (DMIs) expand the collaboration possibilities that were available in traditional acoustic ensembles, allowing musicians to interconnect their instruments, share audio and control data, synchronise their tempo, exchange messages and so on [1]. Many of these collaboration possibilities exist in multi-user instruments, such as the Reactable [9], where all users share the same interface, but they can also be found in ensembles of individual instruments. When the ensemble consists of identical instruments, or when the instruments are designed for a specific performance, as in the case of laptop orchestras [14][10], the collaboration possibilities are often designed directly into the instrument's interface [13]. However, when the ensemble consists of diverse instruments, where each instrument's interface, mappings, and sound processes can vary greatly, the design and integration of collaboration interfaces into the instrument can be challenging, if not infeasible.

These challenges are further exacerbated in the case of spontaneous "jam sessions" where the instruments composing the ensemble, or their sonic identities, may not be known until during a performance. That is, these heterogeneous orchestras may suffer from reduced *awareness* [1]. Therefore, a collaboration interface should provide ways to visually identify the contribution of each instrument [12].

More importantly, a collaboration interface needs to take into account the variations in instrument structure and control interface in order to provide access to the cooperation modes [1] commonly available in digital orchestras, such as sharing controls, exchanging content, and messaging.

In this paper, we investigate the design of collaboration interfaces for heterogeneous orchestras. We focus on the dynamics of sharing control parameter and output data, and the experience of adapting an instrument for collaboration.

1.1 Musical collaboration interfaces

Existing musical collaboration interfaces can be divided into three categories. *Multi-user instruments* often have only a single shared public control space and sound process (e.g. the Reactable [9]), but may include separate private spaces for each musician (as in the Jam-o-drum [2]).

In the case of ensembles of the same instrument (*homogeneous orchestras*), the same collaboration interface can be distributed across musicians, as in LOLC [10] or other pieces for laptop or mobile phone orchestra [7].

In ensembles of diverse instruments (*heterogeneous orchestras*) the cooperation possibilities are often more limited, and may consist of only those controls which are common amongst all instruments, such as tempo synchronisation or audio inputs and outputs. But they usually do not allow shared control of idiosyncratic parameters.

Other collaborative interfaces facilitate communication or awareness by providing shared performance cues [13], or visualisations of each musician's contribution [12].

Our own previous contribution to the field of musical collaboration interfaces, the *bf-pd* library for PureData, provides each musician with a collaboration interface that facilitates communication, awareness, and exchange of control data amongst an ensemble of heterogeneous DMIs [6].

NIME'20, July 21-25, 2020, Royal Birmingham Conservatoire, Birmingham City University, Birmingham, United Kingdom.

Collaboration Interface	**Collab Window**	**Tabletop**
Space	Individual	Shared
Interaction Paradigm	Busses	Graph
Collaboration Visibility	Self only	Self and Others
Granting Access	Per-parameter to all musicians	Per-parameter per-musician

Table 1: Comparing the collaboration interfaces

1.2 Musical group dynamics

Previous research on music collaboration interfaces has focused on group dynamics, and in particular on the social aspect of sharing an instrument, as well as notions of private and public spaces. Fencott [8] compares the use of private and public spaces in a multi-user instrument. Men and Brian-Kinns extend this research to a Virtual Environment [11] with private and public spaces. Cakmak et al. [5] study social interactions in a shared musical virtual space. And Bryan-Kinns [4] investigates social behaviour and interactions in a multi-user networked instrument.

Much of this research has been conducted on distant (networked) collaboration using multi-user instruments. In contrast, our work is focused on co-located orchestras, i.e. musicians in the same physical space, with diverse instruments.

1.3 Contribution

In this paper we study real-time musical collaboration in heterogeneous orchestras, and the effect of interface design on these collaborations. We do this by comparing musicians' experience with two different collaboration interfaces. We present a new touchscreen-based collaboration interface, and we propose principles and guidelines for the design of such collaboration interfaces.

2. COLLABORATION INTERFACES

Our goal is to better facilitate collaboration in heterogeneous orchestras, and to understand how different collaboration interfaces might affect the experience of making music together. So we created two very different collaboration interfaces, which we describe in the following sections.

Both interfaces rely on the BOEUF protocol [6], which requires musicians to declare the *parameters* and *outputs* that they want to share with other musicians. This is done by adding particular software components to their instrument. *Parameters* are user controls, such as *gain* or *cutoff frequency*, while outputs are musical data produced by the instrument, such as note onset events or pitches. Parameters and outputs are defined by a name, a type — which can be *cont* [floating point between 0 and 1], *midi* [integers from 0 to 127], *bool* [boolean] , or *bang* [an event] — and the number of values in the parameter or output.

Table 1 provides a comparison of the two interfaces. They differ in how the interfaces are spatially organised, in their interaction paradigms for managing connections between instruments, in the visibility of the evolving state of the collaboration, and in the way access to parameters is granted. Videos of both interfaces in use are available online. [1]

2.1 Collab Window

The first interface is the collaboration window (or *Collab Window* in this paper) [6]. The Collab Window is privately displayed on each musician's laptop as seen on Figure 3.a. Figure 1.a depicts this interface as seen by one musician (Joe) in an orchestra of three musicians (Joe, Ann, & Mickael). Joe's own instrument and shared parameters and outputs are displayed in the leftmost green column. The two other musicians' instruments are displayed in the grey columns, each with their respective shared parameters and outputs. The graphical interfaces for each parameter and output are automatically generated based on the type and number of values that they contain.

The interaction and collaboration possibilities offered by this interface are illustrated in Figure 1.b, and include that:

- Joe can *set* her own parameters using the white controls in her column
- She can *watch* the others' parameters and outputs with one of her own by assigning them to the same watch bus.
- She can *ask* values for someone else's parameters using the white controls in the others' columns
- When asked for a value for one of her parameters, which is displayed in the grey controls, she can choose to *grab* that value, or *grant* access to the parameter, meaning that future asked values directly modify the parameter

The Collab Window also functions as a means of facilitating awareness amongst the musicians by making all parameter states visible to all musicians and displaying the activity of each as a spectrum next to the instrument name.

2.2 Tabletop

The second interface we investigate (referred to as *Tabletop* in this paper) is a tabletop interaction presented on a touchscreen which the musicians sit around, as shown in Figure 3.b. We designed and implemented this interface for this study, and it is presented in preliminary form here.

Figure 2.a shows what the Tabletop interface would look like from Joe's point of view for the same orchestra. All instruments are displayed in a shared global space as coloured rectangles. The global space also shows connections between instruments as arrows which move when data is being transmitted. Each musician places the interface for their instrument, i.e. their control local space, in front of them. Figure 2.b shows the local control space for Joe's instrument. The top row displays her own parameters and outputs, with graphical controls automatically generated according to the type and number of values. The bottom row displays the other musicians' instruments with their parameters and outputs. The activity of Joe's instrument is displayed as a fading border that expands according to the loudness of the instruments' audio output.

The interaction and collaboration possibilities offered by the tabletop are depicted in Figure 2.b:

- Joe can *set* her own parameters using the controls in her local space
- She can *watch* someone else's parameter or output with her parameters by dragging a line from the other parameter to her own parameter connection slots (as shown between Ann's delay and Joe's pitch in Figure 2.b). This connection is then displayed only in the global space and can be destroyed by pressing a 'break' button displayed above Joe's parameter.
- She can *ask* a value on someone else's parameter using one of her parameters or outputs. To do so, she creates a connection from hers to the other's.
- She can also *ask* a value directly by touching the controls of the other's parameters in her local space.
- When asked for a value on one of her own parameters, three buttons appear above the parameter and she can *grab, grant,* or *break* the connection.

[1] `https://bf-collab.net/video`

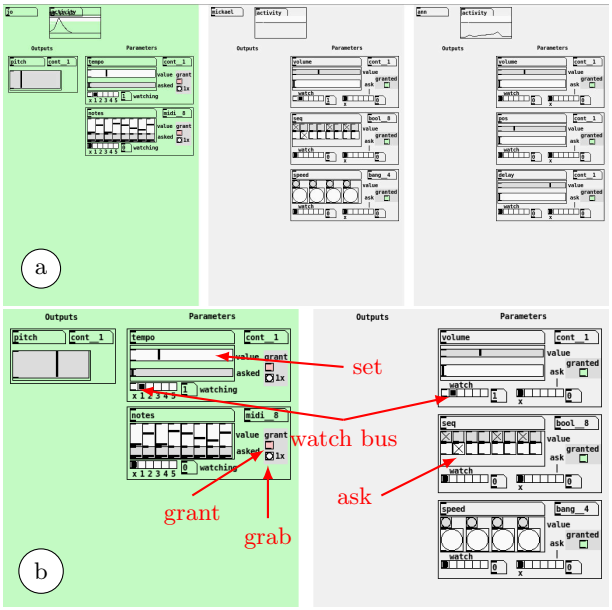

Figure 1: The Collab Window: a) The interface that musician Joe sees. b) Detail of available interactions from Joe's point of view

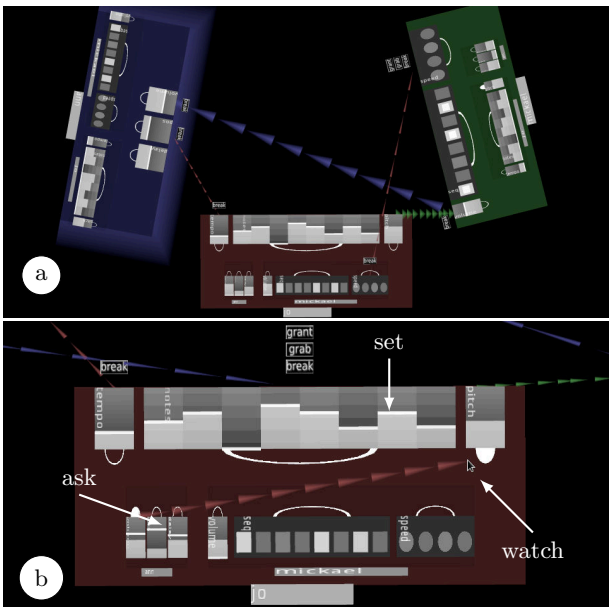

Figure 2: Tabletop: a) Whole interface and b) local space from Joe's point of view

3. QUALITATIVE STUDY

In order to evaluate the effects of interfaces design on musicians' experience of making music together, we conducted a qualitative study where we asked two groups of musicians to create their own instruments using the bf-pd library, and to then play freely improvised music together in two sessions. In one session they used the Collab Window interface, and in the other session they used the TableTop interface.

Our goal was to address a number of questions: What was their experience of using each interface? How did the collaboration interface affect their ability to collaborate, share data between instruments, and share control of their instruments? How did the interface affect the music they made? What was their experience of integrating the bf-pd objects into their instruments?

3.1 Protocol

We recruited two groups of musicians from the communities at University of Virginia and Université de Lille. Each group had 3 participants. The musicians in Group 1 had on average 27 years experience as musicians, 20 years playing electronic or computer music, and 19 years playing electronic music in ensembles. Group 2 had on average 13 years experience as musicians, 6 years making electronic music, and 4 years in electronic music ensembles. The average age was 36 years for Group 1, and 23 years for Group 2. All participants were male.

3.1.1 *Instrument Integration*

We asked each musician to design an instrument in Pure-Data, and to use the bf-pd library in order to facilitate collaboration. We required that each instrument have in total between two and six parameters and outputs. One parameter must be a volume control, and at least one parameter should be a multi-parameter. Multi-parameters or outputs must be of order 8 or less. Musicians did not coordinate their instrument designs beforehand, though they were allowed to make minor modifications between the first and second sessions.

3.1.2 *Sessions*

Each group participated in two separate sessions which took place on different days. Group 1 used the Collab Window in Session 1 and the TableTop interface in Session 2. Group 2 used the TableTop interface in Session 1 and the Collab Window in Session 2. Two members of Group 1 had used the Collab Window interface in a previous focus group, but otherwise all musicians were encountering these interfaces for the first time during the sessions.

Each session had the following structure: 1) The musicians were introduced to the collaboration interface and its mechanics. 2) The musicians tested their instrument with the collaboration interface. 3) Each musician described their instrument and parameters to the group. 4) The musicians performed an improvised "jam session" lasting between 5 and 15 minutes. 5) After a short break, the musicians reset their instruments and then performed a second jam session. 6) We then interviewed the musicians.

During the sessions we recorded logs of all interactions, which we analyse and discuss below. And we conducted semi-structured interviews and discussion after each session.

3.2 Thematic analysis

We conducted a thematic analysis [3] of the transcribed interviews. This involved labelling the interview transcriptions with a large number of codes, then subsequently organising these codes into eleven themes. We present our findings organised into the following four *theme groups*.

3.2.1 *Adapting to Collaboration*

This group includes the themes *Instrument Design*, *Mapping*, *Meta-Instruments* and *Affordances, Limitations, & Characteristics of the System*.

Both groups of musicians strongly indicated that they felt the need to adapt their instruments to the types of interactions that were facilitated by both collaboration interfaces.

A musician from Group 1 said:

> P1: "With this particular interface, it seems like an interesting scenario for instrument design . . . it has to be a specific type of instrument . . . So I

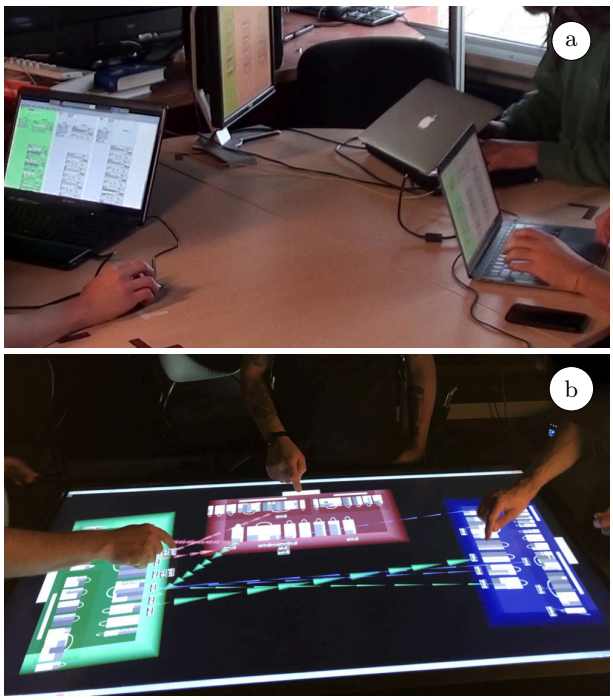

Figure 3: Images from the study sessions with the Collab Window (a) and the Tabletop (b).

> wouldn't necessarily take any of the instruments I've already designed, and plop them in here. [Instead] I would have to sculpt them in a certain way, which I think is fine, but its a distinguishing characteristic of this system."

The musicians saw this form of music-making as distinctly different to an ensemble of non-networked instruments. They described this difference by using such terms as *collaborative composition*, *large multi-user instrument*, *meta-instrument*, *modular instrument*, and *mixing instruments*.

The musicians also felt a similar need to adapt their instruments in order to collaborate more effectively with the particular instruments that the other musicians brought to the session.

The musicians in Group 1 were particularly excited by the ability to construct chains of connections (which they referred to as "feedback loops") where a parameter from one musician is controlling another musician's parameter, which then controls a third.

3.2.2 Group Dynamics

This theme group includes *Group Dynamics*, *Planning & Verbal Communication*, *Composing & Shaping Performance*, and *Exploring, Improvisation, & Unpredictability*.

The musicians in Group 1 — who had significantly more musical experience than those in Group 2 — mentioned concerns that had to do with the dynamics between musicians as well as compositional considerations. As an example of the former, after the TableTop session one musician said:

> P2: "It might be a politeness thing, but I found myself scanning to make sure that if someone was requesting [permission to access a parameter] I was on top of it. I didn't want to leave anyone hanging."

All of the Group 1 musicians expressed an interest in pre-planning and practising together before a performance in order to achieve more developed musical results. For example:

> P1: "I think what would be nice . . . is to spend some time before the session playing . . . to spend even 10 minutes talking like this, and get it to go into an environment where some of the performance is already structured, and then going from there. Because . . . when I think about improvisation I tend to start from nothing and discover my way into it, but for this music-making practice it might be beneficial to collaborate and discuss where to start."

However, Group 1 were also interested in using exploration and unpredictability to discover new sonic potentials. For example one musician said:

> P3: "Just going for it gives you a better frame of reference of what's possible, and then talking."

And another musician strategically used the collaboration capabilities to generate unexpected results:

> P2: "When I wanted more variation in my instrument that I didn't want to come up with myself, I'd look for where the activity is and see who is jiggling lots of faders and follow those. Because innately you know the behaviour of your own patch better than you know others' patches. And partially you want unknown behaviour."

3.2.3 Comparing Interfaces & Preference for the Second Session

This theme group includes *Learning the System*, *Benefits of TableTop*, *Benefits of Collab Window*, and *Attention Demands*.

After Session 2 both groups of musicians offered comparisons between the two collaboration interfaces. Interestingly, both groups expressed a preference for the interface they used in Session 2! (For Group 1 this was the TableTop interface and for Group 2 it was the Collab Window.) We believe this is due in part to the musicians becoming more familiar with the collaboration possibilities that are common to both interfaces. This is supported by musicians mentioning a desire for more time to learn the system.

The Group 2 musicians preferred the Collab Window for a number of reasons, including: They found it simpler to use and more efficient for making and breaking connections. They were more familiar with the bus metaphor it employs. And they preferred controlling their instruments from their own laptop, rather than from a separate shared interface.

The Group 1 musicians liked that it was easier with the Collab Window to avoid accidentally creating a connection, and that they did not have to grant permission to every collaboration request. Otherwise, Group 1 had a strong preference for the Tabletop interface. For example, one said:

> P1: "I think the networking possibilities became part of the instrument a lot more with this interface, because we could see all the [data flows]".

And:

> P1: "In this session it was easier to get to a place where it felt like we could actually perform! And we got there much faster. And as a result of this we got to more interesting sound worlds."

Both groups appreciated the greater efficiency afforded by the Tabletop's multitouch capability. For example, musicians can change multiple sliders at once.

Both groups also mentioned how the more visually rich interface increased visibility and awareness, which contributed to a greater sense of playing together. From Group 1:

> P1: "Depending on the networks or the feedback we setup, the slider I would move would also respond as the result of someone else's information. So, seeing the part of the interface you're engaging with change because of somebody else's action, that was an important part of that."

And from Group 2 :

> P4: "With the Tabletop we were not each isolated behind our screen. We're on a shared table, and even if today we did better with the [Collab Window], with the shared [Tabletop] there was something really good. ... Also on the energy side, there were many connections which were created around the table, we were all there [mimes being with arms extended over the table] almost dancing together."

On the negative side, Group 1 found that the richer interaction interface of the Tabletop, and the need to grant permission for every request added demands to the musicians' attention, which distracted from more musical concerns.

3.2.4 *Challenges, Bugs, & Feature Requests*

Both groups encountered deficiencies in the bf-pd collaboration modes and the two collaboration interfaces. We also received a number of requests for new features.

For example, Group 1 found that both interfaces did not allow the musicians to control their parameters with the precision that they wanted. They found the TableTop somewhat better because the slider widgets were larger. They suggested implementing numerical inputs and displays for setting parameters very precisely. Group 1 also wanted to be able to save and retrieve the state of all connections between instruments.

Group 2 suggested a number of new features for interaction, as well as new modules for audio processing. In particular, they strongly advocated for the possibility of connecting to individual values inside multi-parameters, e.g. to control one step of a sequencer. Though this could have been due to our limitation on the number of parameters, they also wanted to use multi-parameters to group controls on the same sound module, e.g. time and feedback for a delay, which then requires separate watch and ask access. Both groups suggested the option to have permission to all parameters granted by default.

There were also a number of expressions of appreciation with both interfaces. This collaborative mode of music-making was described as "fun", "cool", "engaging", and "more fun than playing alone!"

3.3 Interaction and collaboration logs

We analysed logs of all messages sent between instruments during each session. We detected *gestures* as continuous changes made faster than 2 Hz. And we then measured: *interactions* as gestures made by a musician on their own instrument; *cooperations* as gestures which set someone else's parameter or set one's own parameter from another's parameter or output; and *connections* as all actions that changed the connections between instruments. Figure 4 shows the averaged rate of these actions for each session.

Although our sample size is limited, a few visual observations can be made. The higher number of interactions and

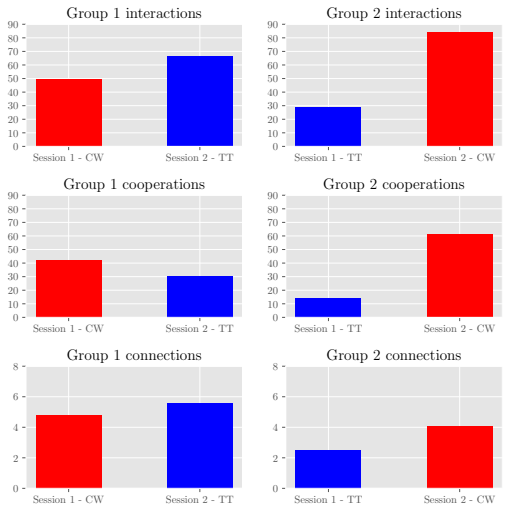

Figure 4: Average interactions, connections, and cooperations per minute for each session. The TableTop (TT) is blue. The Collab Window (CW) is red.

connections in the second sessions for each group corroborates the musicians' comments on the learning curve of the system. This may also be due to musicians' improved competency with their instruments, and increased familiarity with this way of collaborating. Interestingly, the number of cooperations were lower for both groups when using the TableTop. One interpretation of this result, which aligns with our thematic analysis, is that the extra attention demanded by the visualisations, and the need to grant all proposed connections, might have inhibited musicians from asking and watching other's parameters. They may also have constrained their cooperations in order to limit visual overload on the more visually rich TableTop.

4. PRINCIPLES AND GUIDELINES

After considering the results of our study, we propose two principles: *Adapting (to) the System* and *Default to Openness*, and two guidelines for building collaboration interfaces: *Support Development* and *Minimise Friction to Support Expressivity*. Each principle is a viewpoint or an understanding that we were not aware of before we conducted this study. The guidelines are derived from these, and are more concretely actionable.

Adapting (to) the System

Our musicians felt the need to adapt their instruments, both to the forms of collaborating that bf-pd affords, and to the the other musicians' instruments. Before conducting this study, we did not anticipate the degree to which musicians would need or want to adapt to the system.

We originally designed bf-pd to facilitate the use-case of "spontaneous heterogeneous digital orchestras," where the musicians may be unfamiliar with each other and their instruments. However, our musicians, especially Group 1, were very concerned with how to improve the experience of making music together *as a group*, and requested features (such as the ability to save and retrieve the state of connections) to support their ability to develop the music *over time*. In effect, they implicitly rejected our (also implicit)

assumptions about what this system is for. We realise that we, as developers, need to adapt the system *to our users*! Perhaps this is obvious, but we needed this study to remind us to question our assumptions. This leads us to suggest the following guideline:

Support Development

Collaboration interfaces should allow for appropriation by groups of musicians with diverse goals, strategies, and instruments. Musicians should be able to easily adapt how their instruments integrate with the system over time to fit the musical direction taken by the group. Such interfaces should support both spontaneous and more structured collaborations, and facilitate the transition between them.

Default to Openness

When we designed the system of permissions in the BOEUF conceptual framework [1], we assumed that musicians would be protective of their instruments, and would want to selectively allow others to control their parameters. In contrast to our assumptions, the musicians in our study were not worried about letting others access their instrument. From these results we might infer that musicians prefer a principle of "default to openness", making access the default, and restriction the occasional exception.

We also point out that we designed bf-pd to facilitate collaboration in the form of sharing parameter data and control. Perhaps the musicians were taking our tacit cue by expressing their desire for this form of collaboration to be frictionless. By requiring them to grant access to shared parameters, we were unwittingly working against our own goals! Luckily the musicians' feedback made this evident to us. This suggest the following guideline:

Minimise Friction to Support Expressivity

Both groups strongly expressed that they wanted to reduce what we might call "administrative friction". They did not want to dedicate attention to accepting connections and granting permission to their parameters. Collaboration systems should be designed so that the most important activity, *making music together*, occupies the majority of the musicians' time and attention. As one musician said, "P4: If you have to grant all the time, it takes away from playing time!" (The friction of granting individual access may be why cooperations were lower in both Tabletop sessions.)

As we continue to develop these systems, we might reduce friction and support expressivity by, for example, setting all parameters open to collaboration as the default option. We might also provide default outputs for each instrument (for example by extracting features from the audio output), thus facilitating faster collaboration. Lastly, the study made clear the importance of having precise interface widgets for manipulating parameters.

5. CONCLUSION

In this paper we investigated two interfaces for collaboration in orchestras of heterogeneous digital instruments. While there were notable differences, such as the increased visibility, awareness, and enhanced sense of making music together when using the TableTop interface, perhaps the most prominent "result" is that the affordances for collaboration provided by the BOEUF framework, which are common to *both* interfaces, had a significant effect on musicians' experience, instrument design, and the resulting music.

While these results should be qualified by a long-term study with a greater number and diversity of participants, and more diverse instruments, we suggest that designers keep in mind the principles of openness, supporting expressivity, minimising friction, the need for musicians to adapt to the system, and adapting the system to support musicians' ambitions. The DMI design guideline of "a low entry fee, with no ceiling on virtuosity" [15], could be applied to collaborative interfaces as "open for spontaneous collaboration, with support for group appropriation."

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